Submarine Canyons off Eastern Oahu[1]

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ABSTRACT: Submarine canyons studied along the eastern coast of Oahu appear to be of subaerial origin, drowned during island ridge subsidence. Where coarse sediments are well supplied from reefs, and submarine ridges form obstructions, the canyons have been filled and masked. Structures in the Oahu seamount province formerly hypothesized to be of slide origin, appear to be *in situ* volcanic features, and have determined patterns of deposition from the canyons. A more normal-leveed distributary channel may exist in the Hawaiian Deep.

SUBMARINE CANYONS have been recognized extending from the nearshore regions of several of the Hawaiian Islands. Off Molokai and Kauai, Shepard (Shepard and Dill, 1966) mapped canyons very clearly associated with subaerial drainage, and Mathewson (1970) showed the Molokai canyons to be passive at the present time—that is, passing sediments to the deep sea, but preserving the axial gradients established above sea level. Canyons off the east coast of Oahu were noted by Hamilton (1957), and described as terminating near 1,000-fm depth in possible deep-sea fans.

During 1968 and 1969, surveys of the Oahu canyons were undertaken from the University of Hawaii's research vessels R.V. *Teritu* (Subcan I, October 1968) and R.V. *Mahi* (Subcan II, June 1969). Goal of the work was to learn more about the sediment pathways involved in filling the Hawaiian Deep (moat) and about the history of the canyons themselves. Track lines of these cruises are shown in Fig. 1. The *Teritu* collected echo soundings on an Ocean Sonics GDR-T recorder along tracks controlled by visual bearings, radar ranges and bearings, and Loran *A*. The *Mahi* tracks were similarly controlled, but were not as accurately positioned due to poor Loran reception, and the lack of range marker and true bearing modes on the *Mahi* radar. Along the *Mahi* tracks reflection profiles were obtained using airgun and sparker sources.

Two distinct groups of canyons occur along the coastline (Fig. 2). From Makapuu Point to Mokapu Point five canyons are present with broad U-shaped profiles, and wall heights of

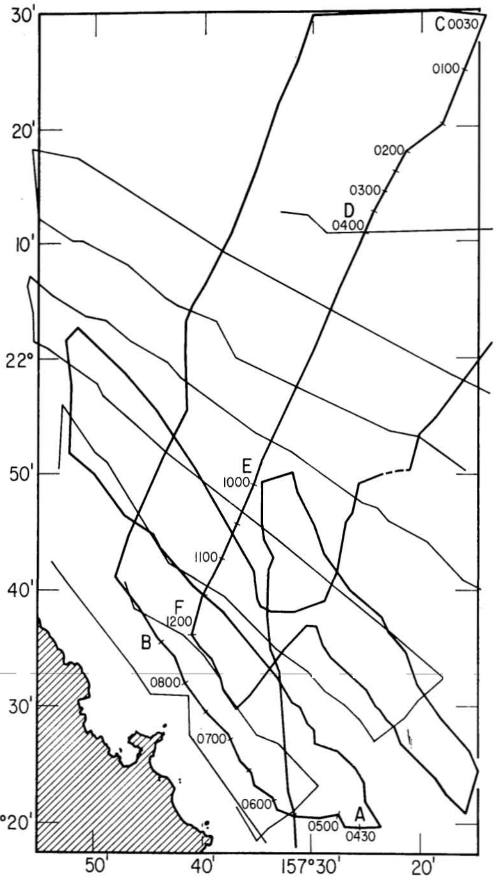

FIG. 1. Survey tracks. R.V. *Teritu*—light lines; R.V. *Mahi*—heavy lines.

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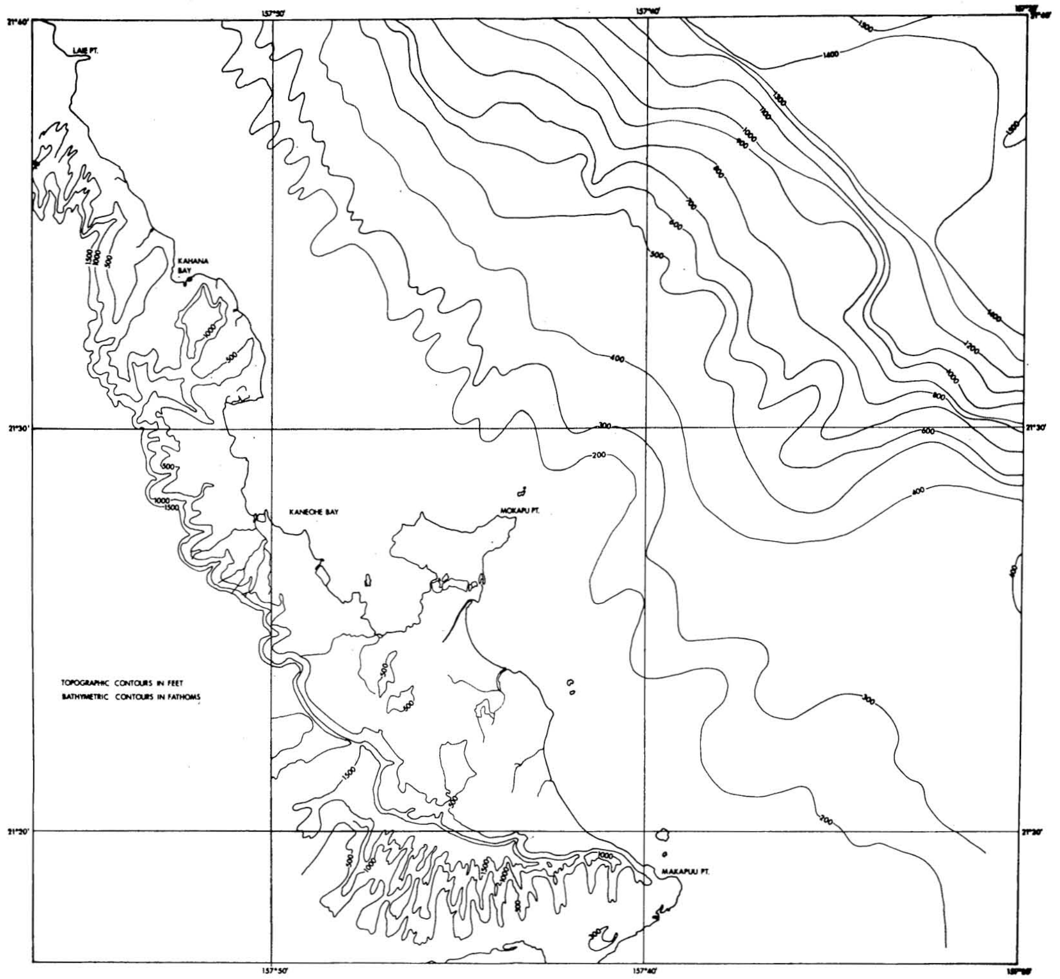

FIG. 2. Nearshore canyon bathymetry (contours in fm) and subaerial topography (contours in ft).

35 to 152 fm. Deepest portions of the valley floors are to the left looking downstream, and two of the valleys have smaller V-shaped notches cut into their floors.

From Mokapu Point to Laie there are 17 canyons, all much narrower than the Makapuu group and show definite V-shaped cross sections, with wall heights of 25 to 100 fm. The Mokapu-Laie group are distinctly associated with land canyons, and typically head off the bay mouths—e.g., Kahana canyon and Kahana Bay. Subaerial erosion between Makapuu Point and Mokapu Point has produced a broad coastal plain, and eliminated obvious land-marine relationships, and the area is protected by a developing barrier reef. Some of the canyons head off the passages through the reef, suggesting the possibility of previous connection to subaerial patterns, if, as has been suggested elsewhere (Goreau, 1959), these passes do indeed represent preserved basement lows.

Figures 3, 4, and 5 present the bathymetry, basement topography, and the sediment distribution along the slope based on the *Mahi* reflection profiles. It is immediately apparent that the Makapuu-Mokapu canyons have been extensively filled in their upper sections. Figure 6 is a line drawing from a reflection profile crossing the canyon heads (line *A–B* in Fig. 1). Filling has progressed upward in the valley

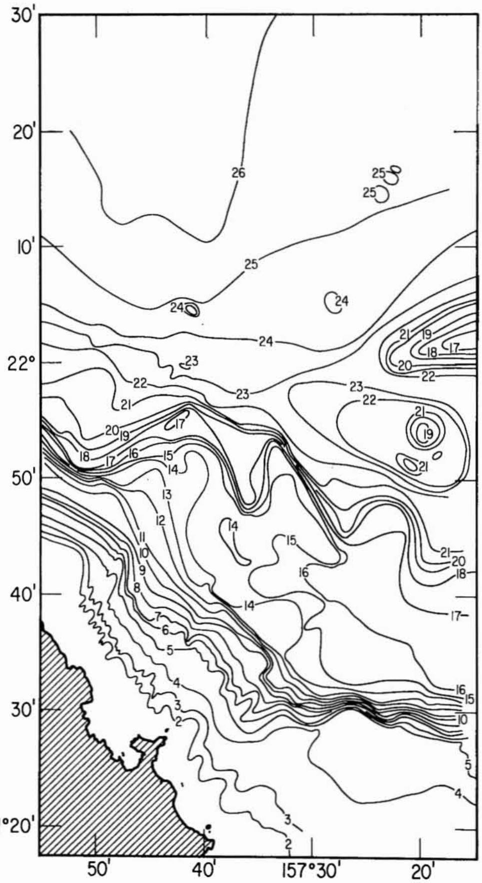

FIG. 3. Bathymetry, contours in hundreds of fathoms.

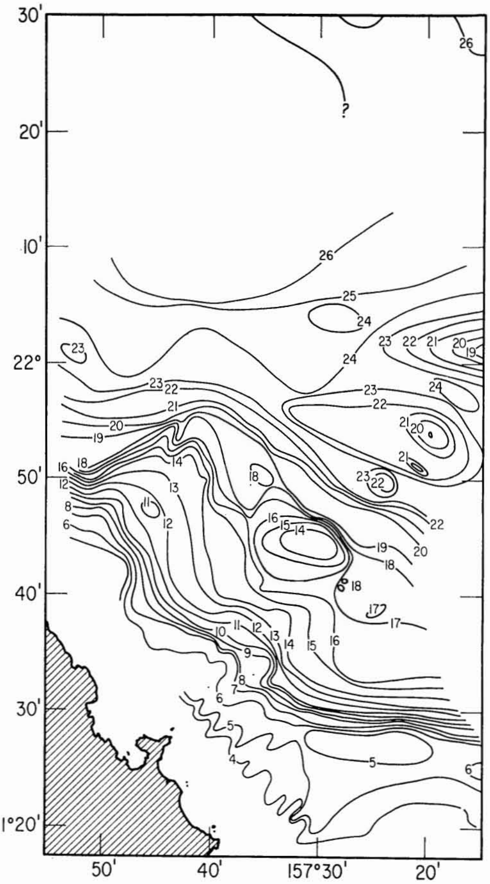

FIG. 4. Basement structure map, contours in hundreds of fathoms.

floors until nearly reaching the top of the basement cuts, at which point it becomes conformable to the surface profile. Because of equipment problems, reflection profiles were not obtained over the heads of the Mokapu-Laie canyons, but their well-defined V-shapes suggest that little sediment fill has accumulated in their axes. A comparison of the two groups shows the southern basement topography and the northern surface topography to be quite similar in shape, slope, and canyon density. It would appear that the development of the reef-lagoon system to the south has been very influential in filling and smoothing the southern canyons by overfilling. Slope differences have also influenced development. The southern section is marked by several prominent and relatively shallow basement ridges and deeper seamounts which have acted to retard sediment movement to the Hawaiian Deep; whereas, to the north, steep slopes persist to greater depths, and ridges that are traceable along the slope become narrower and deeper. One of the southern canyons, the only canyon known to originate offshore of a headland (Hamilton, 1957), heads just east of Makapuu Point. Drainage through this canyon is to the east and southeast; however, the canyon was not adequately covered in the surveys to permit discussion.

Canyons of both groups coalesce rapidly on the steep slopes between 600 and 1,100 fm. At this point three main drainage pathways pass

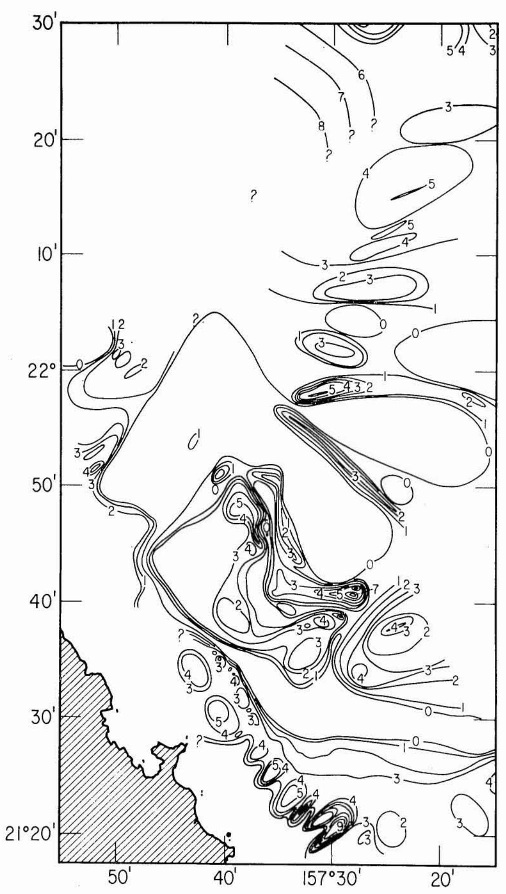

FIG. 5. Isopach map of sediment distribution, contours in 0.1 seconds.

sediment to the Deep (Fig. 7). The northernmost pathway is the smallest of the three. Slopes in that region are steeper and the ledges narrower so that sediment deposits which outline the courses are poorly developed. The two main courses drain the major Mokapu-Laie canyons and the northern Makapuu-Mokapu canyons, respectively. They trend northeast, but are interrupted by a basement ridge at 1,500 fm. Sediment-ponding occurs behind this ridge and also beyond it in a divide between the ridge and a small seamount, with accumulations of up to 500 m occurring in these areas. The deeper accumulation is the only well-defined fan deposit. Other bulges in the deep contours are the result of basement topography. The two courses merge in a northerly direction to pass the seamount group, and diverge as they reach the upper portion of the moat. Basement configuration has been the principal control for depositional patterns, with filling in the lows, and well-developed channels following the lower slopes of topographic highs where the confining effect would be expected to produce higher current velocities (Andrews, 1970; Johnson and Johnson, 1969). In Fig. 6 ponding on the lower ridge area can be clearly seen (line *E–F*) with evidence of mass sliding to the area, the slope sediments prograding over the trapped deposits. Sediments which bypass the ridge traps do so mainly through the canyons and channels.

One perplexing occurrence in the depositional patterns is the presence of what appear to be rather normal onlapping levee structures along profile *C–D* (Fig. 6) well out into the moat. This type of structure is rather well documented from a variety of deep-sea fans (e.g., Andrews, 1970; Normark, 1970), but in this instance the structures are well beyond the apparent canyon terminus near 700–1,000 fm and the lobate fan structure in the seamount region at 1,700 fm. Only one reflection profile exists through this area, so that it is not possible to determine the existence of any well-defined distributary channels which might be responsible for these features. There is clear inference of large volume transport by turbidity currents along specific channels into the moat. However, an alternative hypothesis should not be excluded due to the scarcity of data. Ballard (1966) and Andrews (1967) have documented gravity slide structures on low slopes of the continental rise of eastern North America and, from this point of view, we infer that the overlapping structures may represent mass slide structures originating as fan deposits become overloaded on the higher slopes. However, the obstructing presence of numerous seamounts make this mechanism less feasible, and future workers in the area should be alert to the possibility of a complex distributary pattern feeding the Hawaiian Deep.

The appearance of the Mokapu-Laie canyons and the strong subaerial-submarine relationships

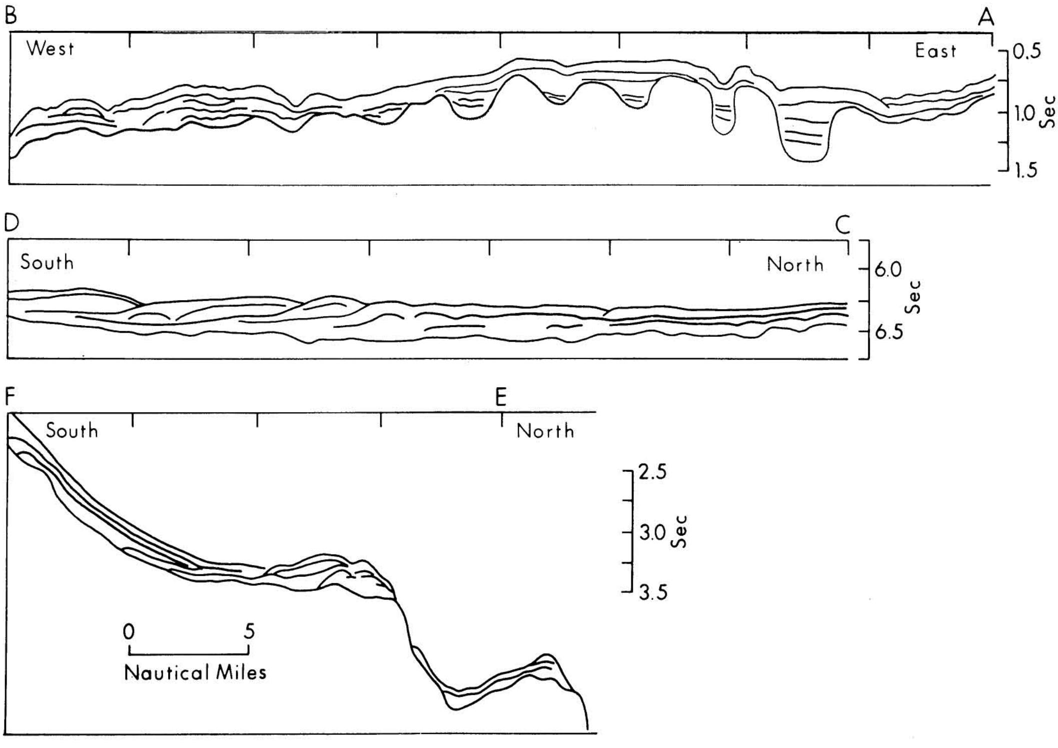

FIG. 6. Airgun profiles: *A–B,* Makapuu-Mokapu canyon heads; *C–D,* levee structures in moat; *E–F,* slump ponding on ridge.

which exist, together with the high degree of filling of the Makapuu-Mokapu canyons, strongly suggests that the canyons were initially subaerial features which have drowned as the island ridge subsided. The distribution of canyon filling and recent reef development suggest that the fill (up to 600 m) may be related to this reef growth and sediment production. Where canyon-stream connections are clear and are unimpeded by reefs, filling is minimal and canyon shapes unmodified. This would not be unexpected, considering the degree of weathering affecting sediments on the windward sides of subtropical high islands—a large amount of the material being removed as clays rather than as sands and silt.

The well-established pattern of fill around the Oahu seamount province to the south, and the lack of distortion in these sediments suggest that the seamounts are original basement highs —presumably volcanic—and not slide blocks, as suggested by Moore (1964). High reflectivity of the bottom sediments prevented complete penetration of the sediment fill in the moat on the reflection profiles, but profiles taken earlier by Kroenke (1965) indicate minimum filling of 600 to 1,000 m. Subsidence of 2–3 km which has been inferred for the island ridge from seismic refraction work and gravity analysis (Strange, Woollard, and Rose, 1965) agrees well with the 1,800-m termination of well-defined subaerially formed canyons.

CONCLUSIONS

Canyons along the east coast of Oahu are principally subaerial canyons which at present are acting as pathways for sediments moving to the Hawaiian Deep. Reef sediments from the well-developed reefs of the southern portion of the coast have filled canyons of that region very effectively. Basement configuration has dictated

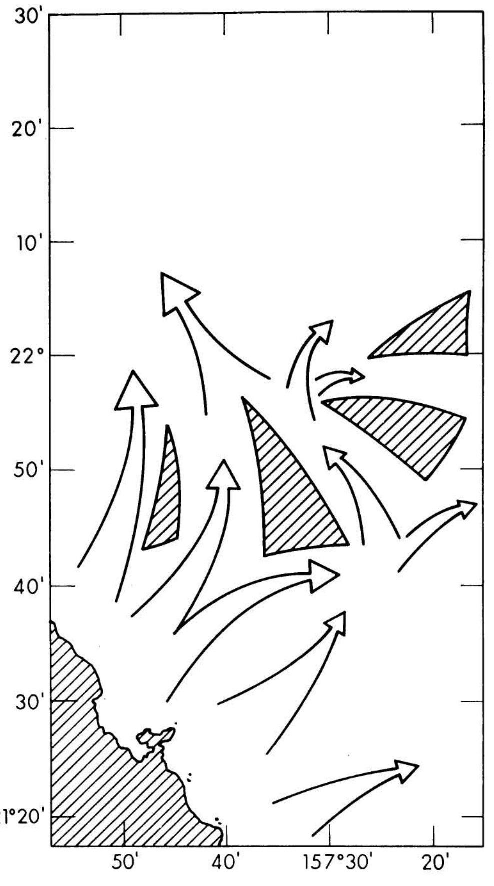

FIG. 7. Generalized sediment transport pathways and basement structures.

sediment deposition and transport patterns, and the basement highs are probably not slide blocks but small volcanic structures *in situ.*

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